Title of Invention:	**A MOTOR DRIVEN SAMPLING APPARATUS FOR MATERIAL COLLECTION**
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A MOTOR DRIVEN SAMPLING APPARATUS FOR MATERIAL COLLECTION

BACKGROUND OF THE INVENTION

1. Field of Invention

Micro-sampling devices are conventionally used to slice/cut, scoop, punch or bore samples from source materials such as paper, cloth, wood, gels, human and animal tissues and the like. The samples collected may undergo wet chemical treatment; may be examined microscopically, used to create tissue micro-array slides, or be further chemically analyzed by a variety of analytical equipment including pyrolysis gas chromatographs, mass spectrometers, scanning electron microscopes and Fourier infrared spectrometers.

A widely available and commonly used micro-sampling tool is the garden variety paper punch. These tools are manually operated and available a craft stores or business supply outlets. They have been routinely used to sample dried blood stored on blood cards or for sampling leaves in the study of crop genetic events. There are also dedicated, electric, automated punches, with large footprints designed for high throughput sampling. These systems require the user to manually feed a blood card which, when punched, automatically delivers the sample to an extraction vial, well plate, or other receptacle. These systems are designed for punching dried blood on archival blood cards only.

Paper sampling is used in the neonatal, forensic and genomic markets to analyze blood for a variety of components. Blood samples are collected on filter paper cards and then allowed to dry. A small disc of paper bearing blood is then punched from the card. The blood may then be analyzed for genetic events, diseases, proteins, enzymes or other specific component.

Typically punches are constructed of a punch and die. When operated they create a shearing action thereby tearing the disc of paper from the source card. Writing bond paper is lighter and therefore thinner and a more tightly woven product than filter type papers (i.e. coffee filter papers for example). With lighter bond papers, the shearing action of the punch and die during the punching operation creates little or no artefact fibres. This paper however, does not have the desired absorbent quality required to store blood. Blood samples and other related body fluids (i.e. saliva) are stored on thicker filter paper. This type of paper product is characterized by a loose fibre matrix. Therefore the punch/die shearing operation when punching a sample from such paper will result in the creation of associated artefact fibres. When punching filter paper bearing blood paper fibre artefacts bearing blood will be generated which may be transferred to the next sample punched and into the collection vial receiving the sample. Therefore conventional paper punching systems when used to sample blood cards generate artefacts

which may lead to cross contamination.

Bench top, large footprint, automated electric punches have several moving parts both associated with the punching mechanism and the x-y translational stage holding plates or racks of vials below the die. With high throughput these systems generate static. The artefact fiber that are created may be controlled under certain conditions (i.e. de-ionization or other anti-static devices) or the sample may be randomly distributed and not delivered to the desired location. With increased usage static can build quickly and result in artefacts becoming airborne, resulting in carry over and cross contamination. The static may affect delivery of the punched disc down the delivery column resulting in non-delivery, sticking or delivery with a subsequently punched sample doubling up in a single vial.

The racks to receive the samples on the automated punches are positioned below a platen on which the paper sample is positioned for punching. Therefore the operator has no line of sight to confirm that the sample punched has been delivered to the correct vial and whether cross contamination has occurred.

Manual punches, if used for high throughput sampling of blood cards in place of more expensive automated systems, may result in repetitive stress injuries (RSI) over time to the wrist.

This new invention offers a combination of unique features including:

- An electric motorized coring operation thereby reducing repetitive stress associated with manual punching and coring devices;
- A coring mechanism and not a punch and die punching mechanism, eliminating the creation of paper fibre artefacts and associated cross contamination;
- An absence of static build up, a contributing factor to potential cross contamination and carry over of artefacts to other samples or vials;
- A completely open line of sight concept insuring sampling of the desired target area and correct delivery to the preferred vial location;
- Increased sampling diameters made possible by a plurality of cutting sleeves and can be quickly exchanged;
- A simultaneous cutting, lifting and storage of the sample from the source material;
- Absence of repetitive stress injury (RSI) associated with manual punches;
- Rapid change of sampling tips and tip diameters; and,
- Increased throughput without a corresponding increase in the size of the unit.

2. Description of Prior Art

Paper punches such as the Fiskars® crafters punch or other single hole stationary punches are widely

available. These punches are inexpensive to purchase, simple to operate and offer a range in punch/die diameters from 1/16th inch to 1/4 inch. The sample may be carefully punched from specific source materials such as paper and the sample delivered directly into the collection well or easily collected after punching with the aid of a tweezers or other forceps, and then inserted into the extraction vial. These manual punches generate little or no static compared with large automated electric punches. However, there are several limitations which make these devices a less than desirable tool for extracting dried blood samples from blood cards.

Paper punches are constructed with the punch and die open and not in contact. This is maintained by a biasing spring mechanism. This allows sample blood cards, within a limited ranges of thicknesses, to be quickly and easily inserted into the punch throat for punching. The area of interest to be punched can be quickly positioned below the base of the punch. The punch may be operated in one hand with the other hand used to hold the source card. This is a suitable method of sample extraction for low sampling programs where the source sample is of suitable thickness and surface dimension.

The punching action for this type of punch occurs when the top and bottom levers are squeezed together in one hand, using the thumb on top and the remaining fingers below. Due to the tension of the spring this operation can create fatigue in the finger, hand and wrist muscles after only a few sample punches are produced, and increase in fatigue over a lengthier period of repetitive punching. Therefore repetitive stress injury may develop quickly with this type of punch where even the smallest sampling pools to be collected become an arduous and painful task.

While the punch and die on this unit remain open at all times allowing for quick insertion of source material for sampling, the vertical height of the throat between the punch and die on these punches may not be large enough to handle some blood cards of greater thickness, or versatile to sample other materials soft enough to be sampled with this instrument but too thick to be inserted.

Another problem with these punches is that the horizontal length of the throat is limited and therefore may restrict sampling over all surface areas and locations of a particular blood card. For example, the Whatman GeneCard requires sampling with a 7.0 mm punch. The description of use states that a sample may be collected almost from the center of the card. Sampling directly from the center of the card is not possible with a conventional paper punch because the horizontal throat of the punch is less than the distance from the edge of the card to the center of the card. Therefore this type of punch is limited to sampling blood cards with surface dimensions that ensures the card can be inserted to allow the punch to reach any location on the surface where the blood may have collected.

These punches use a punch die mechanism and therefore cut samples by shearing a sample from the source material. The punch pushes the sample through the die, essentially tearing rather than cutting the sample disc. This may generate artefact fibres over time with repeated sampling of fibrous blood cards. If the die and surrounding area on the punch is left uncleaned or uncleared between samples, then these artefacts may build up and result in carry over to the next blood card and subsequently be deposited with the next sample into the extraction vial. Therefore this type of punching device lends itself to cross contamination. These types of punches are restricted in their application to primarily sampling blood cards and cannot suitably sample gels, tissue or other soft substrates. These punches have also been used in the agrosciences to study genetic events in crops such as corn, cotton, sunflower and soya plants. The leaf is inserted in the punch throat similar to a blood card. However, with crop studies, sampling from a single leaf may range from 1 to as many as 12 samples. Because plants have a liquid component in the leaves, repeated sampling allows for a build up of plant saps which cause samples to adhere to the punch and are not easily transferred through the die.

The paper punch is a very common, inexpensive sampling tool for sampling dried blood on blood cards and some other flat samples such as leaves.

Another manual paper sampling device, also inexpensive and widely available is the Harris Uni-Core (U.S. Patent Application No. 20020164272). This tool is constructed of a plastic barrel handle, a stainless steel sharpened coring tip and a spring operated ejection actuator. These coring tools are available in inside diameters ranging from 0.50 to 8.00 mm. There is no lever operation and therefore no throat. This allows such tools to sample from any location on a blood card. However, since there is no punch and die mechanism the sample must rest on a pliable support. The stainless steel end of the coring tool is pushed with one hand into the blood card, leaf sample, gel, paint chip, plastic, etc. with slight rotation and gentle downward pressure. The stainless steel tip may also be used to create custom size micro-filters from large samples of filter paper. The sharpened tip passes through the card and into the pliable under support. The cored sample is retained in the tip where it can be later ejected using the actuator.

Because of the razor sharp cutting tip and absence of lever action, repetitive stress on the hand occurs less frequently over the same sampling period when compared with sampling with a craft paper punch. However, the Uni-Core is still not suited for high throughput as repetitive stress injury will develop with prolonged use. The nature of the cutting tip allows this instrument to be used for sampling a variety of materials including gels, paint chips, food, etc., and to create custom size paper filters. This is a versatile

sampling tool that can be used on a variety of samples of any surface dimension enabling sampling from any location without restriction in size or thickness.

Both the paper punch and Harris Uni-Core are manual punches and are not designed to punch or core a sample directly into a collection vial, however, the paper punch can accomplish this but not with consistent speed and repetition.

A third example of prior art is from IEM Screening Systems (Division of Fundamental Products Company). This company produces both manually operated and electric automated punching systems. The manually operated system consists of a punch which can hold a specific 96 hole blood card and a plastic 96-hole plate directly below the card. The punch automatically moves each time a sample is punched. Each sample is purportedly punched into a collection well in the plastic micro-titre plate located directly below and in registration with the paper blood card. However, delivery of sample is not visible to the operator and therefore cannot be confirmed after each operation. The sample is manually punched and drops directly into a specific extraction vial. Because of the lever action there is less associated repetitive stress injury than with the former two prior art examples, but RSI can occur with prolonged use. Again a punch and die mechanism is used and this can create artefacts and lead to cross contamination. These punches may only be used with specific cards of a corresponding horizontal surface dimension equal to that of the plate. The sample can only be punched from the center of the printed circle on the card where the blood sample has been entered. If the sample is not centre than the punch head will miss the sample. Therefore this punch mechanism requires sample cards prepared in a specific manner to ensure all samples can be reached for punching. This system is also restricted to sampling 96-spot blood cards and only samples with thicknesses equivalent to blood cards. There are similar restrictions on this sampling tool when compared with the Harris Uni-Core.

These former examples of prior art, while functional, are not suited for high throughput sampling regimes, and, with the exception of the Harris Uni-Core, may only be used with blood cards of a limited surface area and thickness. The Harris Uni-Core may be used on samples of a variety of thicknesses and horizontal surface areas.

Neonatal testing of newborns and paternity testing, as well as other large routine blood sampling programs, have necessitated the development of automated punching systems to handle large volumes of blood cards.

Several automated punching systems are available from BSD Technologies (Australia), EMI (USA), Nanometrics (USA), Biorad (USA) and Wallac (USA), Harris Multi-Punch (Canada). Each of these

systems operates on a punch and die mechanism and is designed to punch a single, and sometimes two samples in rapid succession from the same blood card. These systems are only designed to sample blood cards and no other source material.

The sample must be hand fed into the punching region on the automated systems. At this point the punch may be activated with a foot pedal or by pressing a platen upon which the card rests below the punch. Depressing the platen activates the punch.

A plate of uniform footprint but with varying number of holes is positioned below the dye on the punch. After punching, the sample drops down a column into a collection well in the plate. As the next sample is positioned to be punched the plate below the punch/die is automatically moved in the horizontal plane to position the next open well to receive the next punched sample. There are no hopper feeding systems for automated feeding of cards, and therefore each card must be inserted manually. This may create a safety issue as one or both hands may be used and therefore places the operators fingers in the vicinity of the punch. If the operation is not synchronized, the pedal or platen activation may result in operator injury.

The automated punches create static, particularly under dry conditions often encountered during the drier winter months. This may affect delivery of the sample down the delivery column. As well these systems can create artefact fibers due once again to the shearing action of the punch and die which tears the sample. This may result in fibers becoming entangled with samples due to static build up and may lead to cross contamination.

The throat of these units is larger than that for the manual punches, except for the Harris Uni-Core. The thickness may also duplicate that used for paper punches but is not unlimited as is the case with the Harris Uni-Core. These systems offer increased throughput but may not offer the expected confidence that the samples generated are always delivered where expected nor that there is no cross contamination occurring between subsequent samplings. Contamination becomes a chronic condition of these sampling tools which is not always easy to monitor nor are the systems designed to monitor the creation and dispersion of such artefacts.

The new invention combines several features in the prior art. The new invention continues to use the same sharpened coring tip that is used on the Harris Uni-Core. This ensures that a sample from the source material is cut and not sheared or torn, and therefore does not generate artefact contaminant fibres. The new invention is electric and a motor turns the coring tip. This is now a semi-automatic system similar to the electric punching units mentioned in the prior art. However, because there is no

punching and therefore fewer moving parts in contact there is little or not static created. Therefore the new invention is electric but does not generate the associated static characteristic of the larger electric automated punching systems. The motorized coring operation eliminates the need to rotate the coring barrel as is required on the Harris Uni-Core. Therefore there is reduced RSI. The unit may be operated in one hand thereby allowing the sample to be positioned with the other hand, similar to the automated systems. However, the new invention is not a punch and therefore the sample is not directed into an unseen collection vial or well. Instead the sample is retained in the coring tip as occurs with the prior art Harris Uni-Core. The sample may now be directed into a well or vial and the operator can visually confirm delivery, which is not possible on the prior art automated punching systems. As the new invention is electric it is designed to allow the operator to process more cards with minimal RSI. As the new invention uses a coring tip and is not restricted by a throat as occurs on stationary paper punches, the new invention may sample any location on samples of unlimited surface size. The tips are disposable and can be easily replaced which is not possible with the prior art manual or automated punching systems. This new invention is designed to further reduce RSI by being contoured to be held in a familiar position in the hand similar to holding an automated/manual pipette (i.e. Eppendorf® pipette) or a video game joystick.

The distal sharpened edge of the tubular cutting sleeve passes through the source material and cuts into the backing support. This operation, in combination with the backing support, forces the extracted sample to be subsequently lodged in the distal end of the tubular cutting sleeve. The sample is then dislodged from temporary storage by forcing it out with an ejection rod.

There are disadvantages with the prior art coring tools, most notably the susceptibility of the operator to Repetitive Stress Injury (RSI) and more specifically Carpal Tunnel Syndrome (CTS), a condition which interferes with the use of the hand and is caused when too much pressure is put on the nerve that runs through the wrist. Even minimal use of the manual coring device over short periods of time has lead to reported wrist discomfort. This discomfort is acerbated when the manual coring device is used in high throughput sampling environments requiring extended daily use by a single operator. The mild, periodic discomfort may lead to more chronic pain such as arthritis. The operation of the manual coring tool requires finger gripping, downward vertical wrist pressure and repeated lateral turning of the wrist in a semi clockwise/counterclockwise direction.

The new invention incorporates the original unique properties of the prior art manual coring tool but has been ergonomically designed to reduce and/or eliminate RSI and CTS. The tubular cutting tip is

operated from an electric drive, rotating the tubular cutting sleeve thereby eliminating lateral rotation of the wrist. The wrist does not become fatigued and sore thereby increasing continual use of the instrument. The wrist remains in the preferred neutral straight position when operating the motor driven coring device. Vertical downward motion translation is minimal as the design of this new invention places the cutting edge of the tubular cutting tip in close proximity to the surface of the source material to be sampled. The rotation of the cutting sleeve by the electric motor greatly reduces the required downward pressure, as the sharp edge of the tubular cutting sleeve slices through the source material with minimal contact force. The hollow clamshell handle is vertical and can be held comfortably in either hand. The tubular handle rests in the palm of the hand, and is contoured to accommodate the fingers. There is a thumb rest on the reverse to rest the thumb when not punching or ejecting. At the base of the clamshell handle there is a transverse widening of the body. This allows the base of the hand gripping the instrument to rest on this flange. This hand rest at the base also acts to provide support and protection against the hand slipping into the rotating sample sleeve. The tubular handle is modeled after the familiar joystick design. The wide use of joysticks for extended video gaming has resulted in the evolution of an ergonomic design that minimizes RSI. The rotation of the tubular cutting sleeve is driven by two spur gears juxtaposed within the hollow clamshell. The motor output shaft is mated to a step down spur gear which reduces the speed of rotation of the output shaft. The electric driven tubular cutting sleeve offers the necessary means to conduct high throughput sampling over extended daily periods with minimal or no development of RSI. This high throughput is synonymous with that expected from the electric punch devices discussed earlier. The sharp edge of the tubular cutting sleeve combined with the motor driven rotation of the tubular cutting sleeve reduces the required downward pressure commonly needed and applied when using the manual coring tools. The motor driven cutting sleeve will also allow for cutting of thicker substrate materials without the required downward pressure used with the manual coring tools.

In this new invention, as with the prior art, the sample sleeve serves both as a cutting tool and as a temporary storage receptacle to retain the sample and should be replaced frequently to ensure a sharp edge. The sample ejection system enables quick, safe and clean removal of the sample from the cutting sleeve, either in a rapid action for quick throughput into a collection vial, or more slowly, to position sample on a sampling stage. The electric drive minimizes physical exertion and the contoured surfaces of the clamshell handle are ergonomically designed to fit the hand. The combination of these two characteristics enables the tool to be used in that position for extended periods, with minimal RSI risks.

Sample sleeves are held in the drive shaft with a collet system so as to be easily removable for size changes; sterilization or replacement. A single dedicated ejection rod is used in association with a range of different diameter sample sleeves.

This motor driven sampling device was designed for high throughput sampling of dried blood on blood cards or sampling of any other material on media or in situ. Prior art describes a manually operated coring tool which requires finger, hand and wrist movement to core a sample. When used in high throughput sampling regimes this can, and does, lead to repetitive stress injury (RSI). This new electric coring tool has been ergonomically designed to reduce and eliminate RSI from occurring as a result of long term repeated coring operations. The tool rests comfortably in the hand and is gripped by the entire hand encircling the tubular handle. With the finger resting in front, the thumb resting on top and the base of the hand resting on an enlarged rest area at the base, similar to holding a video game joystick.

The hollow tip on this new invention allows for the collection of many samples unlike that of the automated punching system.

Replacement of sample sleeves is realized by a spindle lock mechanism which allows the collet nut to be loosened. The tip slides out and a new tip is inserted. The drive shaft incorporates a shoulder so that the sample sleeves are consistently installed to the same position. The collet nut is finger tightened to lock the tip in position. The ejection rod remains inside the sample sleeve until ejection is required.

A search did not disclose any prior art electric coring tools for sample collecting. One reference refers to a prior patent application for a manual coring tool (Harris). A second patent refers to a battery operated coring tool for coring vegetables and fruits (Dolah).

Canadian Patent Application

2,345,911 Harris

United States

5,852,875 Dolah

SUMMARY OF INVENTION

The present invention is an electric sample cutting and collection apparatus comprising a hollow clamshell casing with a contoured grip for the fingers, a horizontal curve extension to eliminate slippage when held in palm, a thumb rest on top and a hand rest at the base of the hollow clamshell casing where a sample sleeve extends downwards from the base. Within the hollow clamshell casing an electric motor is mounted which drives, via spur gears, the sample sleeve in a rotational manner. The end of the sample

sleeve, distal from the hand rest, is a cutting edge circumscribing a circular region. An ejection rod slides reciprocally within the sample sleeve between a retracted stowed position and an expulsion position. A user cuts a sample from a source material by engaging contact between the cutting edge of the sample sleeve and the source material, applying pressure against the sample and activating the electric drive to rotate the sample sleeve. The sample cut from the source material becomes lodged within the hollow of the sample sleeve. Actuation of the ejection rod from the retracted and stowed position towards the expulsion position displaces the sample from the hollow of the sample sleeve into an appropriate collecting vessel. The automatic return of the ejection rod is comprised of a compression spring that biases the ejection rod in the retracted and stowed position. Samples may be collected *in situ* or on a sample substrate. The unit is a symmetric design to be held in either hand like a video game joy stick, with the base of the hand resting on the enlarged flange at the base of the hollow clamshell casing. The grip is grasped in the palm with the front fingers wrapped around the blended contours with the thumb resting on a flat area at the top and to the rear of the hollow clamshell casing. The unit may be operated with either hand. This ergonomic design avoids using the wrist in a bent (flexed), extended, or twisted position for long periods of time. The unit has been sculpted to complement the contours of the human hand, and the design of the apparatus allows the wrist to maintain a neutral (straight) position. The whole hand is used to grasp the handle and can sit on an enlarged hand rest. The thumb also rests on a flat area within easy reach the activation and ejection buttons located at the top. The device is not asymmetrical, thus equally usable in a one-handed manner by either hand.

In this invention, the sample sleeve serves both as a cutting tool and as a temporary storage receptacle to transfer the sample. The sample ejection system enables quick, safe and clean removal of the sample from the sample sleeve. The electric drive eliminates manual exertion by eliminating the need for reciprocating rotary motion of the hand and wrist needed to core a sample from the source material. Eliminating the wrist action in this new invention allows for the operation of the device with the wrist in the neutral or straight position, eliminating stress to the hand. The hollow casing is held by the entire hand and not the fingers, again reducing another contributing source of wrist and hand stress.

This invention may use a plurality of tubular sample sleeves of different diameter so a single sample sleeve is held in the distal end of the apparatus below the hand rest, by a collet system. Below the hand rest is a spindle lock button, to permit tightening and loosening of the collet nut. This collet lock system allows easy removal of the tubular cutting sleeves for cleaning, replacement or size change.

The addition of a motor to rotate the cutting sleeve, together with the ergonomic design of the tool,

eliminates repetitive stress related injury resulting from prior art manual coring and punching devices. The electric motor used to rotate the cutting sleeve eliminates the reciprocating rotary action of the wrist required for the Harris Uni-Core. The hollow clamshell casing allows the coring tool to be comfortably gripped in the palm with the fingers wrapped in front and the thumb on top like a video game joystick. This is a design many people are familiar with, given the widespread use of joysticks or manual Eppendorf® pipettes, thereby making this coring design less foreign when initially used and easily accepted to the hand. The positioning of the activation trigger is such that it can be easily reached with either hand, minimizing stress.

The motorized rotation of the sample sleeve and ergonomic design allow for repeated sampling with minimal strain on the hand. It also yields an increased sampling range as the system is capable of sampling a wider variety of source materials of increased thicknesses requiring longer cutting times. The tool is designed to accommodate a specific size range of sample sleeves while using the same ejection rod.

The collet nut, which locks the sample sleeves, can be released by depressing a spindle lock button on the bottom side of the hand rest and turning the collet nut counter-clockwise as viewed from the sample sleeve. The collet nut can be loosened for subsequent removal of the sample sleeves, allowing for cleaning of the sample sleeve ejector rod or replacement of the sample sleeve. The collet nut can be removed to allow access to the collet, which can also be cleaned and replaced as required.

The arrangement and locations of the activation and ejection rod buttons leaves one hand free. This allows the operator to position and hold the source material and acquire a collecting vessel for ejection of sample with one hand, while the other hand operates the apparatus.

This device may be used optionally in conjunction with a substrate upon which the source material is positioned.

The present invention allows the user to portion appropriate size samples from source materials such as food, plants, agricultural materials, gels, clothing, paint chips, film, paper, human or animal tissue and substrates bearing source materials to be sampled such as ink on paper, blood on filter paper, blood on cloth, other biological stains on cloth, etc. This present invention may also be used to create circular micro-filters from large samples of filter paper. Sampling is accomplished by placing the desired source material on the surface of a substrate and penetrating the source material to be sampled with a sharp cutting tool by applying downward pressure, thus the surface of the substrate is also penetrated but not perforated. These and other advantages of the invention will be more particularly realized by a reading

of the following detailed description of the invention together with the drawings in which like reference numerals refer to like parts throughout.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an isometric view showing a preferred embodiment of a sample collection apparatus constructed in accordance with the principles of the invention, with the spindle lock button to allow the tightening and release of the collet nut, the motor actuator button, the ejection button, the hand rest at the base of the grip, finger contours at the top and to the front of the grip and a curved finger hook extending in the front and above the finger contours.

FIG. **1A** is an isometric view showing a preferred embodiment of a sample collection apparatus constructed in accordance with the principles of the invention, with the spindle lock button to allow the tightening and release of the collet nut, the motor actuator button, the ejection button, the hand rest at the base of the grip and finger contours at the top and to the front of the grip.

FIG. **2** is an overhead view along the primary axis of the hollow tubular clamshell casing.

FIG. **3** is a projected front view of the apparatus, showing the motor actuation button, ejection button and the collet lock button.

FIG. **4** is a projected side view, with some detail removed for clarity (motor drive assembly), showing the contents of the right hand side of the hollow clamshell casing. It includes the ejection button, compression spring, ejection shaft, plastic spur gears, bearings, collet nut and sample sleeve.

FIG. **5** is a projected side view, with some detail removed for clarity (i.e. ejection assembly), showing the contents of the left hand side of the hollow clamshell casing. It includes the motor actuation button, motor, aluminum spur gear, strain release and power cord.

FIG. **6** is an exploded view of the apparatus, showing the details of the sub-assemblies in the apparatus.

FIG. **7** is an isometric view of the apparatus held in the right hand in the operation of extracting a sample from a source material resting on a substrate. The thumb operates the motor actuation button and the ejection button. This view shows a preferred embodiment of a sample collection apparatus constructed in accordance with the principles of the invention, with the collet nut, the motor actuator button, the ejection button, the hand rest at the base of the grip, finger contours at the top and to the front of the grip and a curved finger hook extending in the front and above the finger contours.

FIG. **8** is an overhead view along the primary axis **B-B** of the hollow clamshell casing.

FIG. **8A** is a partial view of section **B-B** in the lower portion of the apparatus showing the ejection rod in the retracted and stowed position.

FIG. **8B** is a partial view of section **B-B** in the lower portion of the apparatus, showing the spindle lock button and the ejection rod in the expulsion position.

FIG. **8C** is a partial view of section **B-B** in the lower portion of the apparatus, showing the spindle lock button engaged in the primary drive shaft.

FIG. **9** is an isometric detail view of the sample sleeve and collet system of the apparatus.

FIG. **9A** is a partial detailed view of the apparatus along the axis **A-A** of the sample sleeve, as seen from the bottom.

FIG. **9B** is a projected section view of the sample sleeve clamping system of the apparatus along the axis **A-A** of the sample sleeve, showing the primary drive shaft, collet nut, collet, and sample sleeve.

FIG. **10** is an isometric view of the apparatus held in the right hand with the sample sleeve above a receptacle. The thumb depresses the ejection button, expelling the sample in the desired location.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to Figure **1**, a preferred embodiment of a sample collection device constructed in accordance with the principles of the invention is shown. A handle feature **100** blends to a horizontal flange feature **110** at the bottom as a hollow clamshell casing. A collet nut **140** at the lower end below the flange **110** holds the sample sleeve **150**. To facilitate ease of holding the unit, finger contours **120** are included on the front of the casing. To reduce slipping of the hollow clamshell handle **100** through the hand a curved extension shaped as a hook **130** has also been added as a blended feature above the finger contours **120**. The motor actuation button **160** and the ejection button **170** are positioned at the top of the hollow clamshell casing **100**. The spindle lock button **180** extends just below the base of flange **110**. The power supply cord **190** extends from a cord strain release **200** which extends from the rim of the flange **110**.

Figure **1A** repeats the embodiments described for Figure **1** but does not include the blended horizontal extension **130** from the front and at the top of the apparatus which reduces slippage but may not be always a desired feature. All components described in Figures 2 to 10 for the invention with the blended finger hook extension are present in the same invention without this blended extension and have not been shown.

Figures **2** and **3** repeat the preferred embodiments described for Figure **1** but are an overhead view and a projected front view of the hollow clamshell casing **100** showing the motor actuation button control **160**, ejection button **170** and spindle lock button **180** just under the flange **110**. Spindle lock button **180** is hidden under the flange **110** in Figure 2 and cannot be seen.

Figure **4** shows a projected side view of the apparatus in which the thumb rest **210** can be better realized at the upper end of the hollow clamshell casing **100**. The ejection button **170** is biased in the retracted and stowed position by a compression coil spring **220**. The ejection rod **300** is recessed in sample sleeve **150.** Thumb rest **210** is positioned below, and on an angle from the motor actuation button **160** and ejection button **170.** A push button, normally open, momentary switch **230**, which activates the gear motor **240**, is positioned below the motor actuation button **160** (see Figure **5**). The ejection button **170,** located at the top of the top of the vertical blended boss on the hollow clamshell casing **100**, is attached to an ejection shaft **250**. The ejection shaft **250** is attached to shaft collar **260** which is biased by spring **210**, shown in the stowed position. Ejection shaft **250** includes 2 opposing co-planar 90° bends **270** and **280**, separated by a short horizontal span **290** to axial align the ejection rod **300** with the sample sleeve **150**. The ejection shaft **250** passes through plastic spur gear **310** terminating within primary drive shaft **320**. The ejection rod **300** is pressure fitted into the ejection shaft **250** within primary drive shaft **320** (see Figures **8A** to **8C**). Gear motor **240** has an aluminum spur gear **330** (see Figure **5**) meshing with plastic spur gear **310**.

Figure **5** repeats the preferred embodiments described in Figures **1** to **4** and is a projected side view of the hollow clamshell casing **100**. When motor actuation button **160** is depressed it activates the push button switch **230** to start gear motor **240**, which drives aluminum spur gear **330** which meshes with plastic spur gear **310** and turns sample sleeve **150**. When ejection button **170** is depressed it compresses spring **220** and causes ejection shaft **250** with attached ejection rod **300** to travel from retracted position to expulsion position. When spindle lock button **180** is depressed it protrudes into through-hole **340** in primary shaft **320** preventing rotation of the primary drive shaft **320** (See Figure **6**). This enables tightening and loosening of the collet nut **140** for releasing the sample sleeve **150** for cleaning or size change. Sample sleeves **150** within a plurality of diameters can be matched to the various collets **350** that fit the primary drive shaft **320** (See Figures **8A** and **8C**)

Figure **6** is an exploded view with both sides of the clamshell casing **100** moved to reveal the drive sub-assembly. Electrical power is provided to a low voltage gear motor **240** from power cord **190** via the push button switch **230**. An aluminum spur gear **330** is attached to the output shaft **370** (within gear motor **240** and not shown) of the gear motor **240** in position to mesh with another plastic spur gear **310** on the primary drive shaft **320**. The use and configuration of standard spur gears **310** and **330** in this embodiment enables the hollow clamshell casing **100** to be in an ergonomically suitable configuration

for the hand to hold above the source sample material **380** (see Figure **7**). The primary drive shaft **320** is located between two bearings **360** (upper) and **370** (lower). The upper bearing **360** is used to maintain correct radial alignment of spur gears **310** and **330** and the lower bearing **370** is positioned to suit the axial forces expected during sample cutting. The lower end **390** (see Figures **8A** to **8C**) of the primary drive shaft **320** is threaded to attach the collet nut **140** that compresses the collet **350**, which holds the sample sleeve **150.** The spindle lock mechanism showing the spindle lock button **180**, which is biased in the stowed position by a leaf spring **440**. When the spindle lock button **180** is depressed, the cylindrical face **450** on the spindle lock button **180** travels to the through the hole in leaf spring **440** and further into through-hole **340** in primary shaft **320** preventing rotation of the primary drive shaft **320** .

Figure **7** is an isometric view of the apparatus held in the right hand, showing the sample sleeve **150** above a sample material **380** to be sampled. Source sample material **380** rests on top of substrate **400.** The motor actuation button **160** is depressed to activate the motor **240**, which drives the sample sleeve **150.** Gentle downward pressure is applied and a sample is cored from the source sample material **380.** A sample **410**, having been cut as described above, is shown ejected beyond sample sleeve **150** into sample collection receptacle **420** (See Figure **10**).

Figure **8** is a top view of the apparatus, looking along the axis **B-B** of the sample sleeve **150.** Figure **8A** is a detailed section view of Figure **8** showing the internal sub-assemblies in the retracted and stowed position. The spindle lock mechanism showing the spindle lock button 180 biased to a stowed position by a leaf spring **440** and with the ejection shaft **250** and ejection rod **300** in the retracted stowed position. A sample **410**, having been cut as described above, is shown temporarily lodge in the end of the sample sleeve **150.**

Figure **8B** is a detailed section view of Figure **8** showing the internal sub-assemblies in the expulsion position. The ejection system is shown in the expulsion position with a compressed spring **220** biasing the ejection shaft **250** and ejection rod **300** towards the expulsion position.

Figure **8C** is a detailed section view of Figure **8** showing the internal sub-assemblies in the locked spindle position. When spindle lock button **180** is depressed, the cylindrical nose **450** at the distal end of the button cylinder extends into a through-hole **340** in the primary drive shaft **320.** This effectively prevents the primary drive shaft **320** from rotating while the collet nut **140** is loosened or tightened as described above.

Figure **9** is an isometric detail view of the sample sleeve clamping system showing the primary drive shaft **320** with the through hole **340** for the cylindrical nose **450** on the spindle lock button **180** and collet

nut **140**.

Figure **9A** is a bottom view, looking up along the axis **A-A** of the sample sleeve **150**.

Figure **9B** is a projected section view of the sample sleeve clamping system, showing the primary drive shaft **320**, collet nut **140**, collet **350** and sample sleeve **150**. The sample sleeve **150** is inserted through collet **350** to a fixed depth in the primary drive shaft **320**, defined by a shoulder **460**. The collet **350** has two conical surfaces where the upper face **470** contacts a corresponding internal conical face **480** on the primary drive shaft **320**. Similarly the lower conical face **490** on the collet **350** contacts a corresponding internal conical surface **500** of the collet nut **140**. When the collet nut **140** is tightened, the collet **350** contracts and clamps the sample sleeve **150** in place, preventing axial or rotational slipping. To release or tighten the collet nut **140** it is necessary to lock the primary drive shaft by depressing the collet lock button **180** and biasing the cylindrical face **450** on the spindle lock button **180** into the through hole **340** on the primary drive shaft **320**. Various collets may be provided to suit a plurality of different diameters of sampling cutting sleeves.

Figure **10** is an isometric view of the apparatus with the ejection rod **300** in the expulsion position. Sample **410** extracted from source material **380** is stored in sample sleeve **150** and ejected by ejection rod **300**.

A preferred embodiment of this invention is the ergonomic design accomplished by the use of juxtaposed spur gears **310** and **330** in Figures **4**, **5** and **6**. This gear arrangement has allowed the device to be constructed such that it is ergonomically sculpted to be held in either hand, in a comfortable position with the hollow clamshell casing **100** resting in the palm of the hand with fingers positioned within the front contours **120** and under the horizontal extension **130** which rests over the forefinger, and thumb on an angular flat surface **210** at the top and to the rear. This handling arrangement is similar to the grip of a video game joystick or an Eppendorf® type pipetting device and is therefore familiar to the operator when holding the invention for the first time.

Still another preferred embodiment also arising from the spur gears **310** and **330** arrangement in Figures **4**, **5** and **6** is the positioning of the actuation **160** and ejection **170** buttons which enables single hand use for both activation of the motor **240** and ejection of the sample **410** by depressing ejection button **170**.

A preferred embodiment is the adoption of a motor **240** to rotate the sample sleeve **150**. This eliminates the use of a manual coring tool that requires more time for the cut cycle and is an undesirable choice for a large number of samples. The use of a manual sampling tool in the past has resulted in

related RSI injury due to lateral and vertical repeated movement of the wrist, required to operate the tool while collecting samples from source material **380**. The motorized rotation of the sample sleeve **150** allows for high throughput sampling and continual use of the device without interruptions or stoppages. Consequently there is reduced strain to the technician's hand and wrist, which is common with the manual coring tool.

Another preferred embodiment is the plurality of different diameter collets **350** and ejection rod **300** diameters that match various sample cutting sleeve **150** sizes can be used.

Another preferred embodiment is the combined sharp cutting edge and rotational motion of the sample sleeve **150.** This is consistent with that of the manual coring devices and eliminates cross contamination between samples. The cutting edge of the sample sleeve **150** combined with the rotational motion which does not shear the source material **380** when collecting a sample **410**, and therefore does not tear the sample, as is common with conventional paper punching devices. Therefore no artefact fibers are created and there is no residue carried over between samples.

Another preferred embodiment is the variable length of the ejection rod **250** and sample sleeve **150** which can be accommodated in the apparatus, thereby allowing for the ejection of sample **410** into deep vials **420** or for extraction of sample **410** from hard to access source materials.

Another preferred embodiment is the location of the ejection shaft **250** down the center of the primary drive shaft **320** thereby allowing ejection rod **300** to fit inside of sample sleeve **150** for the ejection operation of the stored sample **410** from the sample sleeve **150**. No other electric punching device operates with this combined coring, sample storage, and ejecting system.

Another preferred embodiment is the use of the compression spring **220** to bias the ejection shaft **250** in the retracted and stowed position. In high throughput situations, this operation can be completed rapidly, for quick release of sample **410**. Alternatively the ejection may be slower for gradual release and careful positioning of sample **410** onto sample stages or slides, for example.

Another preferred embodiment arising from the motorized rotation of the sample sleeve **150** is that less downward force is required to be applied than is otherwise needed for the manual coring device to cut through the paper sample. The constant circular rotation cuts into the source material **380** with minimal downward pressure. The downward pressure required to excise a sample will vary depending on the physical properties of the source material.

Still another preferred embodiment arising from the motorized rotation is that the sample sleeve **150** is that the device allows for thicker source materials to be sampled without creation of artefact fibers.